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Description of a subset of single events from the BATSE gamma-ray burst data

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Abstract

About 15% of the gamma ray bursts in the BATSE data exhibit a simple light curve, consisting mainly of a single pulse without fine substructures. In 12 of the burst profiles the pulse shapes show a linear rise and decay. Three events have a distinct sharp rise followed by a long, almost exponential decay. Searches based only on a sharp rise selection criterion resulted in 5 more grbs with different profile complexities. In one case, we identify an envelope of fast oscillations with a long, softer tail lasting about 100 seconds.

The majority of the events were detectable at energies above 300 keV, with tentative estimates for fluences that vary between 4.0 x 10^{-8} and 5.4 x 10^{-6} ergs/cm^2. We describe here their general time characteristics (durations, rise-decay times) and their hardness ratios.

1. Introduction

Ever since its activation on April 21, 1991, the Burst and Transient Source Experiment (BATSE) on the Compton Gamma Ray Observatory (CGRO) has been detecting gamma ray bursts at an average rate of one event per day. A detailed description of BATSE is given elsewhere [1]. The data analyzed here have been collected with the Large Area Detectors (LADs). Each LAD has a 2000 cm^2 geometrical area affording very good photon statistics, unprecedented for very weak events. As a result, the majority of the GRB temporal structures emerge with clarity and high level of significance above background. This BATSE attribute has prompted us to devise a tentative morphological classification scheme along the lines of earlier attempts [2], [3], [4]. In general, we distinguish the following three wide groups of bursts:

COMPLEX: Events exhibiting long, multipeaked temporal profiles.
SINGLE: Single pulses without significant temporal substructures.
SPIKES: Very short (< 300 ms) vents that can either exhibit simple or complex profiles on the tens of ms timescale.

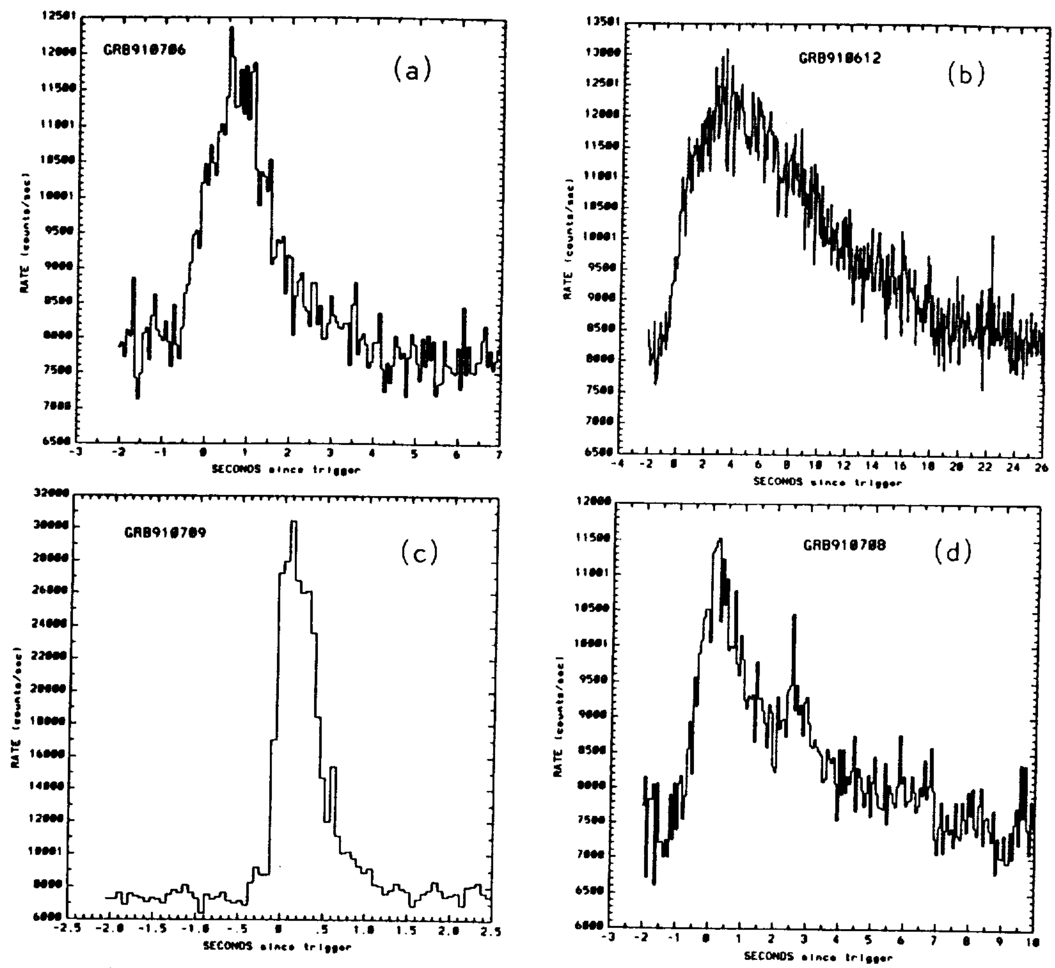

Figure 1. a-d) Typical time profiles of single, smooth grbs. Counts are collected from all 4 channels with 64 ms time resolution.

This classification is strictly morphological and should not be interpreted as reflecting any physical models on the origin of the events at this stage of GRB research. So far all three groups are distributed the same way (isotropically) on the sky [5]. It is rather a convenient division of the database into groups, that could be used to readily select events for different types of analyses, such as Fast Fourier Transforms for the complex events, calculations of rise- decay times for the single events, etc.

2. Data Analysis

(a) Temporal characteristics

In a period of 113 days, between April 21, 1991 and August 11, 1991, BATSE triggered on 100 GRBs. Among these, the subset of single events was selected for simple temporal analysis involving determination of rise-decay times and durations.

The majority of the single events selected had temporal profiles with gradual rises and decays; their shapes were best fitted with triangular-trapezoidal forms. Sometimes a "shoulder" appeared during the decay portion of the event, around 50% of peak level.

Figure 1 shows typical examples of single GRBs. Notice GRB910709 (Fig 1c), which has a peak intensity twice that of the others, an indication that intense events can appear single, countering the "tip of the iceberg" argument. Twelve such events were found in the database.

Several of the selected events had a uniquely characteristic profile with a very sharp rise (< 1 s), accompanied by a long, exponential-like decay (Fig 2a). We searched for more such GRBs in the BATSE data, using only this sharp-rise/exp-decay criterion, and we found a total of 8 events (including 3 single ones). They have been included in this study for completeness, and a progression of their profiles from single to multipeaked and extremely complex is shown in Figure 2 a-d. GRB910814 (Fig 2d) has very fast and non-periodic oscillations at its first part (lasting over 40 s), then it decays slowly for at least 50 more seconds. These events also range in peak intensities and are in general more intense than the first group.

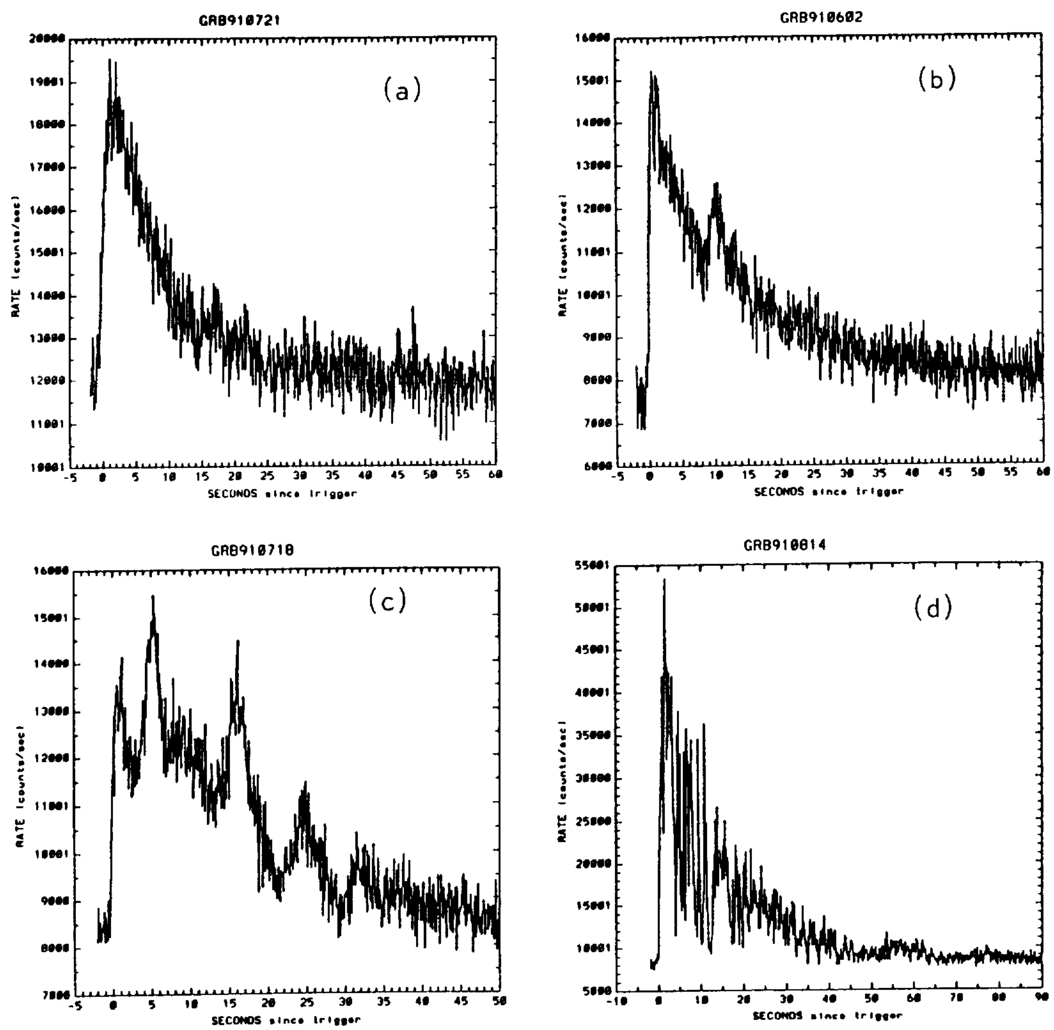

Figure 2. a-d) Examples of grbs with sharp rise, exponential decay time profiles. Notice the progression of the profiles from single (2a) to extremely complex (2d).

Table 1 shows the summary of the GRB temporal and spectral characteristics. We can see from the ratios of their rise times *vs* durations (fifth column) that the majority of the second group has values below 10%, while for the first, this number is above 20%.

We have plotted the rise *vs* decay times for both groups in Figure 3a. We use the cross sign (+) for the first group and the star sign (*) for the second , in all the subsequent plots. Note that the sharp-rise/exp-decay group has a limited range of rise times, below 1 s, as opposed to the wide range of their decay times. In Figure 3b we plot the rise times *vs* peak intensities in counts/s above background. As we mentioned, the second group contains more intense events, while in the first group, events usually peak below 10000 c/s.

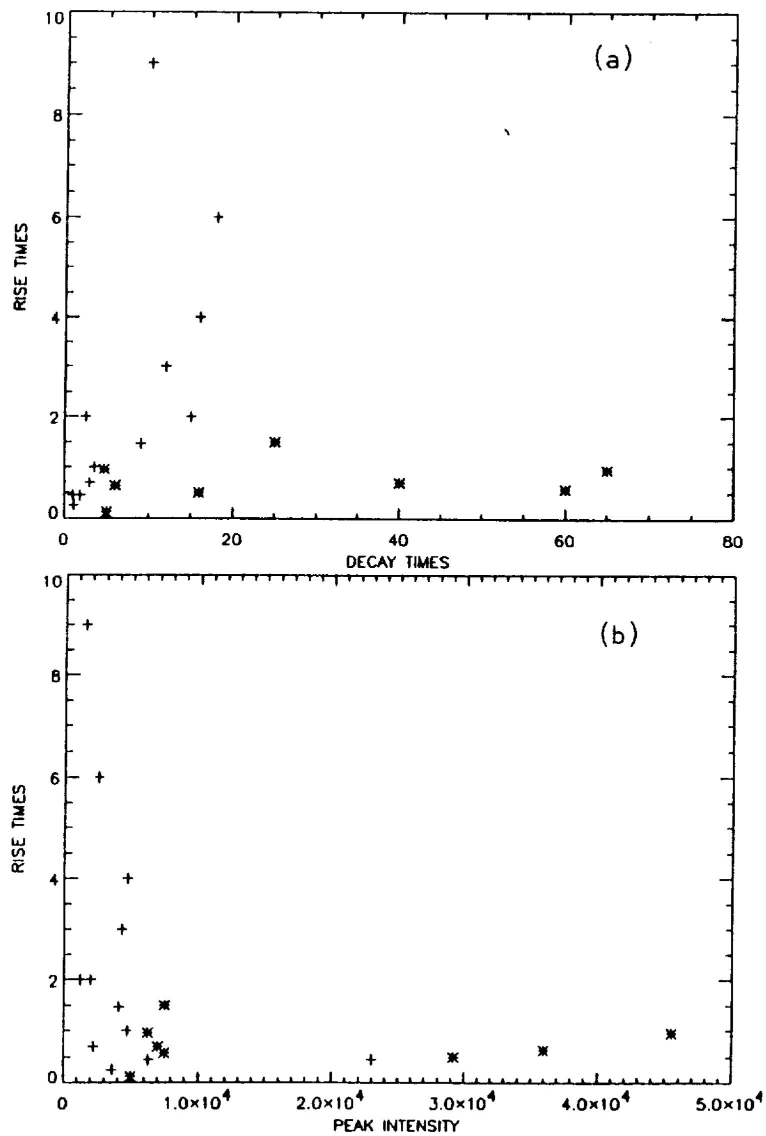

Figure 3. a) Rise *vs* decay times (in seconds) for all 20 grbs. Crosses (+) represent single, smooth events and stars (*) events with sharp rise exponential decay profiles. b) Rise times (in seconds) *vs* peak intensity (above background) summed over all energy channels.

(b) Spectral characteristics

As a first approach we examined the spectral behaviour of both groups in the four discriminator channels of the LADs. The channel energy ranges are defined approximately:

Channel 1 : 25 - 55 keV
Channel 2 : 55 - 100 keV
Channel 3 : 100 - 320 kev
Channel 4 : 320 - 1000 keV

We find that all the single events in the first group do not show any spectral evolution on timescales of 64-ms. Figure 4a shows the alignment of the pulse edge in the two extreme channels (low-high) for GRB910709. In contrast, Figure 4b shows the extreme spectral shift of about 1 s between the same channels observed in GRB910717. In general, spectral evolution is found only in the second group of GRBs.

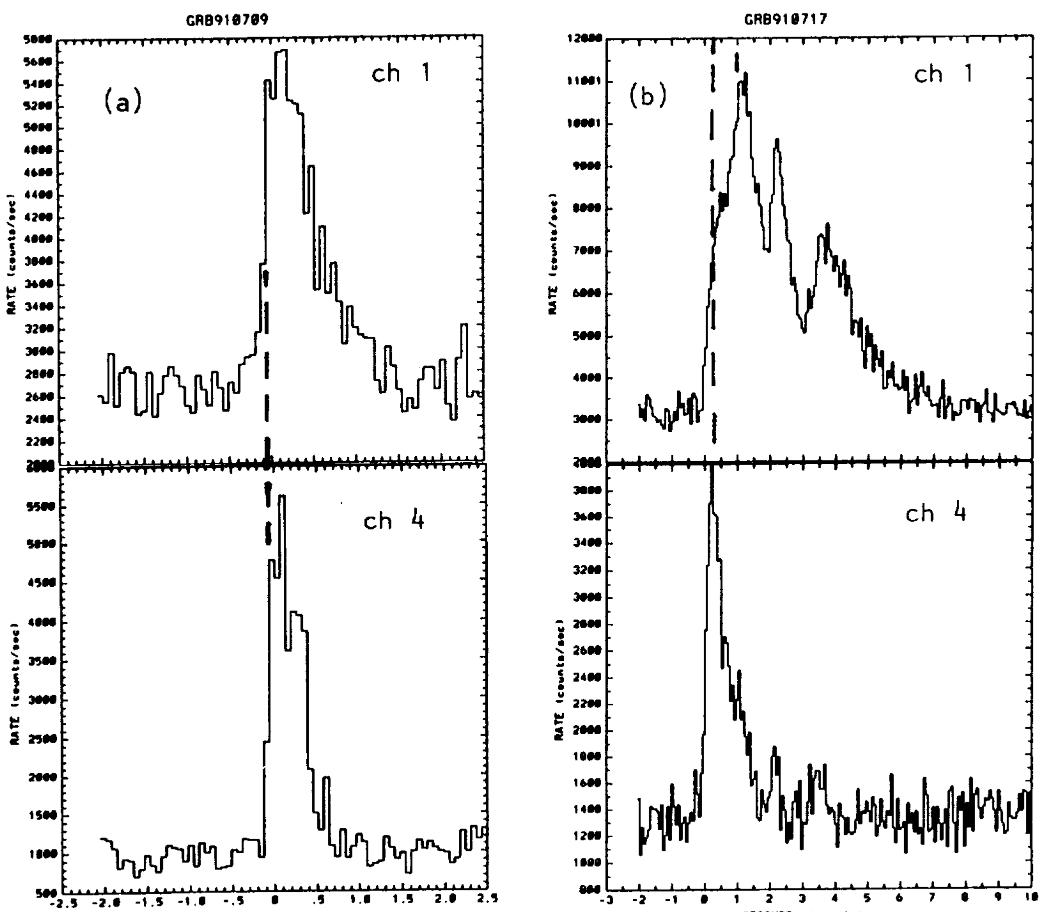

Figure 4. a) Time profile of a group 1 intense event in the two extreme energy channels (low-high). Notice the alignment of the pulse edge (indicated by the broken line) in both channels. b) Time profile of a group 2 intense event in the same energy channels, showing a large shift of about 1 s.

We have computed the hardness ratios (HRs) for all 20 events (see Table 1) by dividing R_3, the background-subtracted rate in channel 3 by R_2, the corresponding rate in channel 2, *i.e.*:

$$HR = \frac{R_3}{R_2}$$

The average HR for the first group is $\sim$ 1.0, while the second group has HRs with an average of 1.6, *i.e.*contains harder events. This result has been confirmed by [6], who estimated the hardness ratios for all BATSE events, and also found this particular group to be a harder subset.

Figure 5 shows the rise times *vs* the HRs. In general the two groups seem well separated in their main characteristics, *i.e.*events with short rise times have high HRs and events with longer rise times have lower HRs.

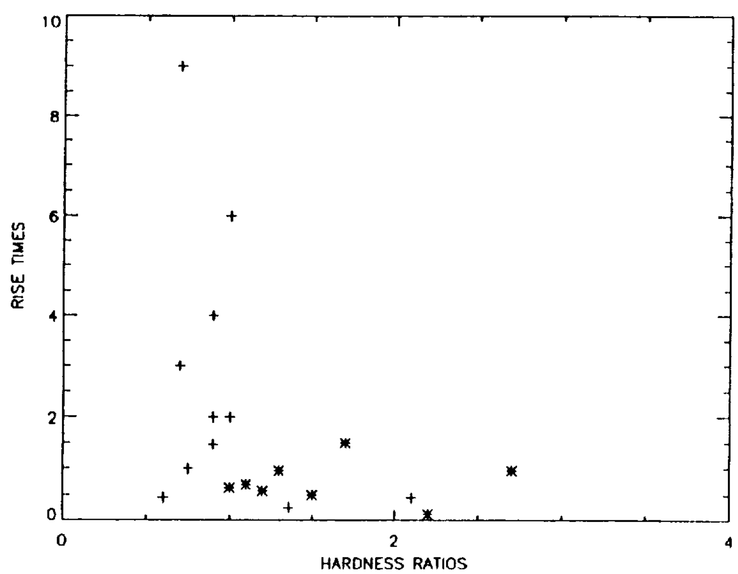

Figure 5. Rise times (in seconds) *vs* hardness ratios for all 20 events. Crosses and stars are the same as above.

3. Conclusions

Table 2 summarizes the statistics of the subset selected from the first 100 GRBs detected by BATSE. In the strictly single events detected, we identify in the majority smooth profiles with rise times usually lasting 25% of the total event duration. These events are usually weaker events, with very low hardness ratios and no evidence for spectral evolution.

In the same subset we identified another group of events with sharp rises and nearly exponential decays, which we then extended to encompass all different complexity time profiles. This group was found to have longer durations with rise times typically 5% of their durations. These events also had higher peak intensities and fluences. In some cases, they exhibited significant spectral evolution from hard to soft.

In summary, we conclude that the first group cannot yet be differentiated from other events in the GRB database on the basis of their spectral or temporal characteristics. We suggest that the second group has spectral and temporal properties distinguished from the majority of GRBs. More detailed spectral analysis is required to provide physical insight into this purely morphological classification.

References

[1] G. J. Fishman *et al.*, in *Proc. GRO Science Workshop,* ed. W. N. Johnson, NASA/Goddard Space Flight Center, 39, 1989.

[2] E. P. Mazets *et al.*, *Academy of Sciences of the USSR*, Report Nos. 630, 631, 632, 1979.

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[5] J. Horack, personal communication.

[6] W. S. Paciesas, paper presented at the GRBs 1991 Workshop in Huntsville, AL., Oct 16-18, 1991.

Table 1. Summary of the GRB Temporal and Spectral Properties.

Group 1

Date	t_r s	t_d s	T s	R	Peak c/s	HR	Fluence[a] ergs/cm^2
GRB910709	0.45	1.50	2.00	28	23000	2.11	7.4x10^{-8}
GRB910708	1.47	9.00	10.47	14	4100	0.90	3.0x10^{-7}
GRB910612	4.00	16.00	20.00	20	4700	0.90	1.8x10^{-6}
GRB910715	0.45	1.90	2.40	19	6300	0.60	4.4x10^{-8}
GRB910809	3.00	12.00	15.00	20	4300	0.70	7.5x10^{-7}
GRB910725	6.00	18.00	24.00	25	2500	1.00	1.4x10^{-6}
GRB910629	2.00	2.50	4.50	44	1200	1.00	3.8x10^{-8}
GRB910805	9.00	10.00	19.00	47	1500	0.70	3.4x10^{-7}
GRB910718	0.70	3.00	3.70	19	2200	1.10	6.6x10^{-8}
GRB910521	0.30	1.00	1.30	19	3600	1.40	1.5x10^{-7}
GRB910706	1.00	3.50	4.50	22	4700	0.80	2.0x10^{-7}
GRB910702	2.00	15.00	17.00	12	2000	0.90	3.0x10^{-7}

Group 2

Date	t_r s	t_d s	T s	R	Peak c/s	HR	Fluence[a] ergs/cm^2
GRB910602	0.57	90.00	90.00	1	7500	1.20	1.1x10^{-6}
GRB910604	0.80	5.00	5.80	13	6300	1.30	1.7x10^{-7}
GRB910629	0.50	16.00	16.50	3	29200	1.50	9.6x10^{-7}
GRB910714	0.13	5.00	5.13	2	5000	2.20	2.3x10^{-7}
GRB910717	0.60	6.00	6.60	10	3600	1.00	2.0x10^{-6}
GRB910718	0.70	40.00	40.70	2	7000	1.10	4.0x10^{-6}
GRB910721	1.50	25.00	26.50	6	7500	1.70	2.5x10^{-6}
GRB910814	1.00	65.00	66.00	1	45500	2.70	1.5x10^{-5}

t_r = rise times, t_d = decay times, T = durations, R = $(t_r/T)*100$,
[a] = Fluences are estimated for the energy range between 60-320 keV

Table 2. Statistics of the analyzed GRB subset.

Total number of GRBs	100
Number of events in subset	20
Events with gradual shapes	12
Events with sharp rise/exp decay shapes	8
Range in durations	3.7 - 90 s
Range in fluences(ergs/cm^2)	4.0x10^{-8} - 1.5x10^{-5}
Range in hardness ratios	0.7 - 2.7
Range in peak intensities(c/s above background)	1200 - 45500